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Culture History of the First Hatchery Generation of Arctic Charr (*Salvelinus alpinus*) from the Fraser River, Labrador (1980-1987)

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ABSTRACT

de March, B.G.E., and R.F. Baker. 1990. Culture history of the first hatchery generation of Arctic charr (Salvelinus alpinus) from the Fraser River, Labrador (1980-1987). Can. Manuscr. Rep. Fish. Aquat. Sci. 2084: iv + 11 p.

The growth of the first hatchery generation of Arctic charr from eggs from the Fraser River, Labrador, is described. Selected stock and families were monitored for seven years. Observations and data related to various experiments with the same strain and to future domestication and breeding programs are summarized.

Key words: aquaculture; quantitative genetics; bioselection; family selection.

RÉSUMÉ

de March, B.G.E., and R.F. Baker. 1990. Culture history of the first hatchery generation of Arctic charr (Salvelinus alpinus) from the Fraser River, Labrador (1980-1987). Can. Manuscr. Rep. Fish. Aquat. Sci. 2084: iv + 11 p.

Le document décrit la croissance de la première génération de l'omble chevalier de pisciculture provenant d'oeufs de la rivière Fraser au Labrador. Un choix de stocks et de familles ont été contrôlés pendant sept ans. Les observations et les données se rapportant à diverses expériences sur la même lignée et aux futurs programmes de domestication et de reproduction sont résumées.

Mots-clés: aquaculture; génétique quantitative; sélection biologique; sélection familiale.

INTRODUCTION

Arctic charr (Salvelinus alpinus) from three locations (Labrador and the Kent Peninsula in Canada, and Norway) have been maintained at the Rockwood Experimental Fish Hatchery of the Department of Fisheries and Oceans, near Gunton, Manitoba, since 1978. During this time the species has shown potential as a specialized aquaculture species with desirable characteristics such as hardiness and good growth at low temperatures (Papst and Hopky 1984, 1989). The 1980 Labrador stock is of special interest since it is the only one which is pedigreed to the collection date. For this reason, the strain is being used for in genetics experiments and in a selection program. Progeny from the 1980 Labrador stock collected have been shipped across Canada, and it is the most common aquaculture strain of charr in Canada.

The culture history of the first hatchery generation and measurements taken during its lifetime are summarized for future reference. Efforts were made to retrieve all available information.

MATERIALS AND METHODS

The following description of the egg collection is taken almost entirely from the description of the collecting trip by R. Baker (1981a). The field trip was performed under the project authority of B. Ayles, with the assistance by the Department of Fisheries and Oceans and officials of the province of Newfoundland. Funding was provided by Algas Resources Ltd., Calgary, Alberta.

Charr eggs were collected on Oct 16, 1980, from a small tributary of the Fraser River about 60 miles from Nain, Labrador (63'30^{o} W, 56'45^{o} N). The river flows from Tesisuak Lake which extends to Nain Bay near the coast. The spawning site was located about 16 km up the river in a shallow pool fed by a small stream from the northwest which then flowed northeast directly into the Fraser River. Water temperature at the site was 4^{o}C.

Personnel arrived late in the spawning season. Approximately 100 charr and brook trout were collected with a seine from the spawning pool and ripe charr were selected when needed for the mating design. Approximately 50% of the charr females had already spawned or had very few eggs to contribute and the males had very little milt remaining. However, the fish appeared healthy. Eggs of individual females were expelled directly into sealable plastic containers. Males were chosen and individually spawned into plastic vials in order to divide the milt between two females. The eggs were fertilized by the dry method. Approximately 25,000 charr eggs were collected. Milt and ovarian fluid samples were taken and preserved in penicillin streptomycin for disease diagnosis. After spawning, the adults were measured and sacrificed and shipped on ice to Halifax, Nova Scotia, for analysis.

Upon fertilization, the eggs were water hardened for 30 minutes and surface disinfected with a 1% iodine solution for a further 10 minutes. Following this, egg containers were packed on ice in coolers and shipped to the Freshwater Institute in Winnipeg. The eggs arrived in Winnipeg on Oct. 17, 1980 and appeared in excellent condition.

Egg from each family were reared separately in Heath incubators at 4.5-5.5^{o}C under quarantine conditions at the Freshwater Institute, Winnipeg. Eggs were periodically flushed with malachite green to inhibit fungal growth. After the parents were certified disease-free, the eyed eggs were transferred to the main hatchery at the Rockwood Experimental Fish Hatchery on Dec. 15, 1980, and incubated at 6.3-6.5^{o}C. Hatching began on Jan. 9, 1981, and fifty percent had hatched by Jan. 14, 1981. Hatching was completed by Jan. 21. Absorption of the yolk sac and swim-up occurred approximately six weeks after hatching during mid-March 1981. Families were reared separately in 61 L (0.60 m^2) fiberglass tanks. At this time, Silver Cup^{R} Trout Feed was introduced to initiate exogenous feeding. During this period, temperatures were maintained between 6.6 and 7.2^{o}C and photoperiod was maintained at a 12L:12D (12 hour light and 12 hours dark) photoperiod.

Families were divided into two groups on Feb. 23, 1981. One group was maintained and monitored as families in the same 61 L tanks, while the other was maintained as hatchery brood stock. R. Baker monitored the growth of the families until July 1982. K. Krieger examined several aspects of the growth and reproduction of the brood stock in 1984 and following years.

At some point in 1981, the Rockwood hatchery switched to Martin^{R} Feed Mills Trout Food. Rainbow trout rations at appropriate pellet sizes and rates were used for the entire life of the fish.

The growth of the charr families was not measured at regular intervals throughout their development. A chronological outline of measurements and culture conditions follows. The 19 families produced will be referred to as F01 to F19.

Apr. 18 to Nov. 25, 1981. Subsamples of 100 fish were weighed on days 16, 41, 59, 94, 143, 164, and 221 after Apr. 18 to estimate the mean weight of fish over time in all families. Results are summarized in Table 2.

Jan. 26 to Mar. 23, 1982. On Jan. 26, all families were reduced to two representative groups of a maximum of 200 fish. A number of families consisted of fewer than 200 fish, in which case all available fish were divided into two groups. Available families were reared at 7°C and 12°C to compare growth at the two temperatures. The massed weight of all fish and fish counts were taken every two weeks. Summary results are given in Table 3. All remaining fish were pooled and reared for future experiments by R.F. Baker.

Families F05, F06, F08, F09, F10, F12, and F19 were divided into two equal halves on Mar. 23, 1982, to maintain densities of fish in tanks below 50-55 kg m^{-3}.

Apr. 20 to Jun. 15, 1982. Massed weights were taken every two weeks between Jan. 26 and Jun. 15, 1982. Summary results are given in Table 4.

Growth was not monitored between June 15 and Nov. 22, 1982. Families were kept on a maintenance diet (2% body wt/day) until a selection program was implemented in Jul. 1983.

Nov. 22-24, 1982. Replicates of families at both temperatures were pooled, and weights and fork lengths of subsamples of approximately half the fish were measured. Results are summarized in Table 5.

Jul. 1983 to May 1986 The lengths and weights of selected fish in three selection categories described below, namely "Selected Families", "Random Selected", and "Mass Selected", were measured between Jul. 1983 and May 1986.

Fish were selected in anticipation of an experiment examining the genetic basis of size differences and the effects of selection. On Jul. 7, 1983, all families within the population, and thus the entire population, were divided into two equal "Random" groups. Seven families with the best growth characteristics, based on growth rates between May 4, 1981 and Jun. 15, 1982, were identified. From one of two "Random" groups, between 8 and 12 of the largest individuals (generally >210 g) were chosen from these 7 families ("Selected Families"). These selected fish represented the largest 10% of fish in each family. The remaining "Random" group was split equally to obtain a "Random Selected" group of 200 fish, and a "Mass Selected" group in which only 70 fish >200 g, with no regard to family, were kept. The "Random Selected" group was kept in a square 1.5 m^3 tank (Tank SA5). Fish in "Selected Families" were branded to identify family, the "Mass Selected" fish received a unique brand, and the two groups were maintained together in an adjacent 1.5 m^3 tank (Tank SA4). Temperatures were maintained at approximately 10C. A Winnipeg photoperiod, ranging from 16L:8D in summer to 8L:16D in winter, was maintained. Mean weights at measured over more than three years in these three selection categories are summarized in Table 6.

In the fall of 1984, some fish reached sexual maturity, and these were spawned to supply eggs and fry to clients. Data on sexual maturation are not available for 1984 or later years. Fertilization rates were measured only for several individual fish used in experiments in 1985 and 1986 (Discussion, de March 1991).

Before July 1984, fork lengths of fish that died were recorded. After this date, both weights and fork lengths of all fish that died or were culled because they were moribund were recorded.

On June 24, 1985, the fish were moved to larger 6.0 m^3 tanks, namely SE1 (Family and Mass selected fish) and SD1 (Random selected fish). Temperatures were maintained near 10°C.

Regressions of log(weight) vs log(length) for selection categories as well as analysis of covariance comparing these regressions were calculated (General Linear Models (GLM) in SAS Institute 1985). Slopes and intercepts were compared using the CONTRAST option.

The breeding experiment comparing offspring from the three described selection categories was not done. However, individuals from the "Selected Families" were bred in both 1985 and 1986. Also, fish from these 19 families, their offspring, and from the brood stock, were examined in other studies which have been identified in the discussion.

RESULTS

Table 1 gives information about the parents and hatching data for the 19 families. Tables 2 to 6 summarize growth data.

Families F04, F08, F05, F12, F19, and F06 had the largest mean weights between May 4 and Nov. 25, 1981. Ranks orders of family mean weights changed only slightly during the next year (Tables 2 and 3). By June 15, 1982, the families with the largest mean weights were F04, F12, F05, F06, F08, F19, and F16 (Table 4). The survey on Nov. 24, 1982 supports a similar trend (Table 5).

Faster growth of juveniles at 12°C than at 7°C is obvious for all families (Table 3).

Approximately 50% of the fish in the three selection categories died between Jul. 1983 and May 1986 (Table 6). The recording of information about mortalities was not consistent, nevertheless, among 142 of 157 possible mortalities recorded, the following information is available. In the Random Selected Group, 8/73 =

11% of the mortalities contained eggs, 6/73 = 8% were emaciated and 4/73 = 5% had extensive fungal growths. In the Mass Selected Group, 2/31 = 6% were identified as emaciated and none were identified as containing eggs. In the Selected families, 3/35 = 9% were identified as containing eggs and none were identified as emaciated. In the Random Selected Group, 4/73 = 5% of all mortalities occurred in the last six months of 1983, 19/73 = 26% in 1984, 39/73 = 53% in 1985, and 11/73 =13% in the first 5 months of 1986. Analogous mortalities were 0%, 32%, 58%, and 10% for the Mass Selected Group and 11%, 29%, 46%, and 24% for the Selected Families. 45% of all mortalities occurred between December and March. This was similar in all three selection categories. In 1985 and 1986, mortalities were often smaller and slimmer than live fish (Mortalities, mean weights of 1006±615 and 1166±539 g and mean lengths of 441±67 and 472±49 mm in 1985 and 1986; Live fish, mean weights of 1408±591 and 1673±740 g and mean lengths of 466±64 and 494±65 mm in 1985 and 1986, means ± 1 standard deviation).

Plots of weight vs length for fish > 200 mm in the three selection categories or as "mortalities" are shown in Fig. 1. Exactly 88 fish <200 mm were not used in the analysis of covariance since these were in all the "Random Selected" group. The regression lines for the three categories were:

Random: log(weight) = 3.21*log(length) - 5.48. R^2=0.916 (n=889, 88 omitted).

Mass: log(weight) = 3.53*log(iength) - 6.34. R^2=0.911 (n=318).

Family: log(weight) = 3.43*log(length) - 6.07. R^2=0.924 (n=318).

Analysis of covariance showed that both the slope and intercept of the "Random Selected" group were significantly lower from those in the two other categories, which were not significantly different from each other. Although there is much overlap and scatter (Fig. 1), the fish from the Selected Families and from the Mass Selected group, were, on the average, plumper than those of the same length from the Random Selected group.

In June 1986, after the last survey, the "Random Selected Group" was reduced to 72 "attractive" fish (mean weight 1660 g, mean length 490 mm, 41 females and 31 males) and the remaining 44 fish were discarded (mean weight 1060 g, mean length 440 mm). In the fall of 1987, none of these females produced eggs. Since none of these animals had been tagged for experiments, it was not known whether the females were sterile or whether they were past their reproductive life.

DISCUSSION

Differences in the size and growth between families were evident at early life stages. Family differences observed at four months after hatching persisted for two years. Also, rank orders were reasonably maintained among the seven selected families. This maintenance of rank orders in Arctic charr families has been observed in other studies, but not over such an extended time period. From a practical point of view, this indicates that selection or culling can take place at early life stages.

Gradual die-off, possibly biased toward emaciated fish and reproducing females, started at four years of age (Table 6). After four years, approximately 20% of remaining fish died each year. This may be due to aging caused by unnaturally high hatchery temperature. Charr in the wild have seldom been observed to mature at three or four years of age, nor do females ripen in consecutive years, as the hatchery charr often do.

In retrospect, we believe that too few families and individuals were saved at the early stages. Although breeding experiments have been done with the selected families, the task of finding sufficient ripe parents in chosen families to obtain a reasonable experimental design has been difficult. Also, females may mature over a span of several months within years, and also may not mature every year. Males, on the other hand, have been ripe and fertile over any desired spawning period. Now in 1990 after additional spawning problems with the second generation of these fish, the re- maining fish are the descendants of only nine of 29 parents originally collected at the Fraser River. If more spawning problems occur, this gene pool might be further reduced.

RELATED STUDIES WITH THE 1980 LABRADOR CHARR

The egg collection is described in more detail by Baker (1981a).

The effects of different temperatures on the survival and development of eyed eggs of this Labrador strain were examined in a study by Baker (1981b). After the eggs were eyed (60 days after fertilization), three groups of 100 eggs were reared at each of four temperatures, 6.3, 8.0, 10.0, and 12° C (12 groups of eggs). Degree-days to 50% hatch were similar at all temperatures, ranging from 475 to 487 degree-days. Complete (100%) hatching occurred at all temperatures. Mean survival to swim-up was 90-97% at 6.3°C, 95-99% at 8.0°C, 73-90% at 10.0°C and 43-59% at 12.0°C. Mean weights ranged from

0.062-0.063g, 0.061-0.066 g, 0.057-0.063 g, and 0.057-0.058 g at the four temperatures respectively.

Krieger (1987) compared the early survival of the three hatchery strains of Arctic charr and rainbow trout. The Labrador charr examined were F1 offspring, obtained in 1984, 1985, and 1986, from the Labrador brood stock. The Labrador charr had fairly low hatching success and larval survivorship compared to other strains of charr and rainbow trout. Larval survivorship improved between 1984 and 1986, probably due to improved rearing techniques.

An extensive series of experiments was conducted using the Labrador charr strain between May and November 1982 (Baker 1983). The effects of temperature and food ration level on the growth rate and conversion efficiency on Labrador charr, Norwegian charr and rainbow trout (Oncorhynchus mykiss), were examined. Signifi- cant intra- and inter-specific differences on most growth parameters were noted. Generally the Labrador charr strain performed better than the Norwegian strain at most temperatures, ratios, and size levels. Differences were larger with increased temperatures. Rainbow trout performed as well as or better than the Labrador strain up to 10°C, but exceed both charr strains at temperatures higher than 10°C.

The effects of increasing density on the growth of Labrador charr and rainbow trout were also examined during 1982 (Baker and Ayles 1990). It was concluded that Arctic charr in 40-200 g range are not suited to cultures at low densities (<40-60 kg/m^3) and are better suited to higher culture densities than rainbow trout.

Tompkins et al. (1987) and Tompkins (1989) compared the hatchery growth of juveniles of the three strains of charr at the Rockwood hatchery. Two families of Labrador charr were compared to families of other strains. The female parent of both families was from Family F05, and the male parents were from Families F05 and F12. Offspring of the same F05 parents was also examined a year later in another study (de March 1991). Tompkins et al. (1987) and Tompkins (1989) reported that the Labrador charr had slightly superior growth rates to Norwegian and Nauyuk charr at 10°C but similar rates at 7° C. It was also reported that the strains could be distinguished on the basis of enzyme systems, but enzyme systems were not related to growth or size.

Both Tabachek (1984) and Yurkowski (1986) conducted nutrition experiments with this stock of Labrador charr. Tabachek fed 12-13 g charr with three open formula rainbow trout diets and found that the diets were acceptable in terms of specific growth rates (2.1-2.2%/day) and feed conversion (1.07-1.15) and resulted in no gross pathological condition over 12 weeks at 12°C.

Yurkowski (1986) evaluated a semi-purified diet and a practical diet (one of the diets used by Tabachek(1984)). While the practical diet was an acceptable diet for the 3 g charr, resulting in good growth and survival and no pathological effects, feeding the semi-purified casein-gelatin diet resulted in high mortality, poor growth, low haemocrits, and an accumulation of glycogen in the liver.

Delabbio and Glebe (1987) and Delabbio et al (1988) examined the sea water tolerance and maturation of the Labrador charr. They are now successfully growing these charr in sea cages.

Both in 1985 and 1986, the first author performed experiments in which the growth of offspring from known parents from the seven selected families was monitored to determine the heri- tability of growth characters. Dams x sires factorial mating designs were used in both studies. The growth of offspring could be related to individual parents (de March 1991). The female parents, F1 to F4, and the males parents, M1 to M4, in the cited manuscript are from the following families respectively: F1=Family F05, F2=Family F06, F3=Family F12, F4=Family F05, M1=Family F04, M2=Family F08, M3=Family F16, M4=Family F05. Not all possible crosses were made. The results are open to interpretation due to within-family size variability. However, the offspring of the parents from Families F12 and F08 had the largest means weights before the age of 100 days. The offspring with both parents from Family F05 were the smallest and the most variable.

The large and seemingly unpredictable size variability exhibited by hatchery charr populations has been of continuing interest at the Rockwood hatchery. Although relationships in this report are weak, they do foreshadow future complications with the Labrador strain. Specifically, defined relationships between mean weights and CV's (standard deviation/mean) of families tend to develop over time in a given experiment, and this relationship differs between strains. The causes are believed to be genetic, not behavioural (de March 1990, 1991; Tompkins 1989).

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Table 1. Information about the parents and crosses. The number of the dam is also the family number in following tables. Length is fork length, converted from rounded 1/2 inches. The number of eggs was from the volume assuming 950 eggs/100 mL.

Dam/ Family Number	Sire Number	Dam Length (cm)	Sire Length (cm)	Approx. no. eggs spawned	Approx. no. eggs incubated	No. juveniles Feb. 23 /1981
F01	M01	49.5	56.0	800	800	664
F02	M01	48.3		2375	950	867
F03	M02	50.8	60.0	800	800	508
F04	M02	52.1		525	525	405
F05	M03	45.7	58.4	2200	950	950
F06	M03	44.5		1400	950	652
F07	M04	43.2	47.0	2950	1040	852
F08	M04	52.1		1400	870	937
F09	M05	47.0	47.0	1400	950	660
F10	M05	47.0		1900	1040	825
F11	M06	54.6	48.3	1600	950	804
F12	M06	47.0		950	950	776
F13	M07	48.3	43.2	2750	950	665
F14	M07	56.0		1200	950	627
F15	M08	47.0	52.1	900	950	804
F16	M08	47.0		2850	950	675
F17	M09	43.2	39.4	1000	950	696
F18	M09	43.2		850	850	660
F19	M10	43.2	43.2	950	950	734

Table 2. Size data between May 4 and Nov. 25, 1981. The mean weights in families (centre column) were estimated on 8 sampling dates (Days 16, 41, 59, 94, 114, 143, 164, and 221 after transfer to tanks on April 18, 1981).

Family Weight Day 16 (g)	Mean Weight overall (g)	Mean Weight Day 221 (g)	Mean
F01	0.165	1.50	3.96
F02	0.192	1.28	3.02
F03	0.125	1.36	3.72
F04	0.210	2.60	8.50
F05	0.257	2.22	5.40
F06	0.146	1.95	5.18
F07	0.175	1.24	3.08
F08	0.201	2.24	5.90
F09	0.211	1.74	4.16
F10	0.176	1.51	4.30
F11	0.262	1.59	3.34
F12	0.262	2.21	5.84
F13	0.156	1.05	2.80
F14	0.127	0.99	3.38
F15	0.230	1.44	3.52
F16	0.126	1.11	2.76
F17	0.283	1.42	2.92
F18	0.305	1.50	3.32
F19	0.381	2.10	4.62

Table 3. Size data between Jan. 26 and Mar.23, 1982. Mean weights of families at 7°C and at 12°C were estimated on 7 fortnightly sampling dates.

Family	Mean Weights (g) on Jan. 26, overall, and Mar. 23			n Range	Mean weights (g) on Jan. 26, overall, and Mar. 23			n Range
	7°C				12°C			
F01	5.78	6.93	8.30	154	6.30	8.65	11.9	154-150
F02	4.06	5.88	8.10	200-199	3.90	6.34	9.67	200-199
F03					5.43	8.15	12.1	116
F04					14.8	22.4	31.2	81-80
F05	9.41	12.8	16.1	200	9.18	12.9	17.4	200-197
F06	9.37	12.7	16.1	200	9.62	13.9	18.7	200-196
F07	4.89	5.88	7.42	200	4.63	5.96	8.23	200-196
F08	8.57	11.4	14.4	200	9.08	13.4	17.9	200
F09	7.51	10.3	13.1	200-187	7.68	10.6	14.6	188-185
F10	7.00	9.73	12.7	200-198	6.86	10.4	14.9	200-199
F11	5.84	7.44	9.21	200-198	5.71	8.76	12.7	200-195
F12	10.6	14.4	18.6	168	10.3	16.0	22.4	168
F13					5.65	8.34	11.8	88-78
F14	3.63	4.67	6.00	123-107	3.33	5.19	7.56	123-106
F15	7.09	10.4	13.46	184-183	8.32	11.7	15.8	184-179
F16	5.43	6.87	8.85	182-180	5.10	8.04	11.9	182
F17	5.08	6.22	7.53	185-184	4.92	6.78	9.54	200-195
F18	5.95	8.02	10.2	200-198	5.44	8.18	11.5	200-178
F19	7.48	10.0	12.7	200-197	7.85	12.46	17.7	200-191

Table 4. Size data between Apr. 20 and Jun. 15, 1982. Several families were split into relicate tanks at the beginning of this period. Mean weights in all families at 7°C and at 12C were estimated on 6 fortnightly sampling dates. Mean weights and number of fish per tank on 20 April, 18 May and 15 June are listed. Family F01 was reported as "accidentally destroyed" on April 6, but measurements were still tabulated.

Family	20 April		18 May		15 June		20 April		18 May		15 June	
	7°C						12°C					
F01			23.0	70	29.9	70	17.8	148	27.7	66	47.4	66
F02	9.84	198	10.6	165	14.4	165	15.8	196	17.7	102	31.5	102
F03							18.6	116	26.6	68	46.2	68
F04							43.5	80	78.9	23	136.8	23
F05	20.8	100	23.8	77	33.8	76	30.3	95	40.9	44	79.4	43
F05	20.8	100	25.9	70	36.0	70	27.5	99	41.2	44	75.7	44
F06	20.1	100	22.9	79	33.8	79	27.6	93	39.8	46	78.9	45
F06	21.2	100	23.1	78	32.9	78	30.6	99	38.2	47	65.0	47
F07	9.30	200	10.9	166	15.1	166	11.9	196	14.3	126	23.8	126
F08	21.1	100	23.3	78	35.6	78	28.1	100	37.3	49	73.6	49
F08	18.5	100	23.6	77	33.1	77	28.4	100	41.2	44	76.8	44
F09	11.8	48	14.0	46	22.1	45	22.6	133	30.3	60	49.2	59
F09	16.3	136	20.7	87	29.6	86						
F10	12.3	50	13.5	49	20.3	49	23.2	99	30.5	60	51.2	60
F10	17.2	148	20.3	89	31.0	89						
F11	11.3	197	12.5	146	17.2	145	20.0	135	23.5	77	39.2	77
F12	23.0	84	40.0	45	61.6	46	30.9	100	39.2	46	73.6	46
F12	27.4	84	30.3	60	45.1	60	38.5	68	47.8	38	85.8	38
F13							16.6	78	22.1	72	37.4	72
F14	7.77	107	8.83	107	13.0	106	11.2	99	12.9	99	21.2	98
F15	17.0	133	20.6	88	28.8	88	21.4	178	30.1	60	54.1	59
F16	11.7	179	13.3	136	18.9	136	18.0	180	28.6	63	53.7	63
F17	9.03	182	10.1	182	13.8	181	14.6	193	19.8	92	38.1	92
F18	12.8	195	16.0	114	12.8	113	16.3	175	24.0	75	42.7	74
F19	18.5	50	21.8	50	36.1	49	29.0	50	37.8	49	64.8	49
F19	16.4	146	19.2	94	28.3	91	27.3	90	36.2	50	65.5	50

Table 5. Size data on Nov. 22-24, 1982. Mean weights, means fork lengths and their standard deviations and ranges are given.

Family	n	Wt±SD ($\bar{g}$)	Range (g)	Lt±SD ($\bar{mm}$)	Range (mm)
F01	26	115 72	26-267	214 48	131-305
F02	50	59 25	11-177	189 34	75-268
F03	31	96 48	32-185	221 36	140-175
F04	12	253 111	70-380	294 51	185-348
F05	41	168 75	12-290	257 45	122-326
F06	45	172 69	35-350	260 41	145-375
F07	58	55 42	12-267	168 37	113-238
F08	45	154 67	48-300	249 38	151-305
F09	30	114 60	14-235	218 43	116-286
F10	28	108 24	48-142	228 24	161-255
F11	34	80 76	9-312	181 54	106-301
F12	42	187 56	8-270	264 36	105-319
F13	34	89 49	21-211	198 32	128-267
F14	20	94 85	31-355	199 50	146-317
F15	29	104 41	16-215	215 32	119-279
F16	29	119 55	24-235	218 36	133-281
F17	37	95 65	21-261	201 50	132-303
F18	32	108 58	18-262	214 43	131-295
F19	49	143 62	27-305	230 41	114-293

Table 6. Weights in selection categories and in selected families taken on Jul. 4-8, 1983; Feb. 1-17, 1983; Jul. 10-12, 1984; Jun. 24-25, 1985; Dec. 19, 1985, and May 22 to Jun. 5, 1986. Mean weights in g (Wt), standard deviations (SD), and number of fish (n), are given, and the ranges of weights in the selected families are given in brackets. The reduction in n is due to mortalities.

Category	Date											
	July 1983			Feb. 1984			July 1984			June 1985			Dec. 1985			May 1986		
	Wt	SD	n	Wt	SD	n	Wt	SD	n	Wt	SD	n	Wt	SD	n	Wt	SD	n
Random Selected	276	137	200	526	271	195	654	358	186	1141	537	157	1290	546	124	1428	593	115
Mass Selected	454	53	70	772	222	68	971	389	65	1722	543	45	1900	364	35	2178	608	35
Selected Families																		
F04	544	134	8	991	195	7	1198	360	6	2126	629	7	2325	238	4	2973	516	4
	(375-735)			(740-1360			(880-1780)			(935-2880)			(2080-2600)			(2425-3415)		
F05	333	40	10	899	275	10	935	256	10	1475	254	7	1642	481	6	1751	719	6
	(280-390)			(610-1390)			(580-1345)			(1110-1950)			(930-2380)			(485-2595)		
F06	333	29	10	776	302	10	942	244	10	1392	516	6	1834	375	5	2184	674	7
	(300-380)			(510-1410)			(600-1300)			(710-2240)			(1380-2350)			(1300-3140)		
F08	293	25	10	654	222	10	979	248	9	1669	665	7	1794	716	7	1653	741	6
	(260-330)			(310-1090)			(680-1390)			(570-2330)			(740-3060)			(420-2300)		
F12	353	33	12	731	154	11	832	260	11	1754	346	6	1938	313	6	2470	459	2
	(260-330)			(490-930)			(410-1350)			(1225-2280)			(1470-2360)			(2145-2795)		
F16	338	37	10	612	150	9	610	238	8	1464	751	4	1632	683	4	1601	685	4
	(285-390)			(320-790)			(280-1120)			(870-2560)			(1180-2650)			(915-2450)		
F19	287	44	10	542	190	10	637	222	9	1316	459	10	1567	520	7	1464	749	4
	(215-340)			(320-920)			(370-1090)			(655-2065)			(740-2190)			(470-2260)		

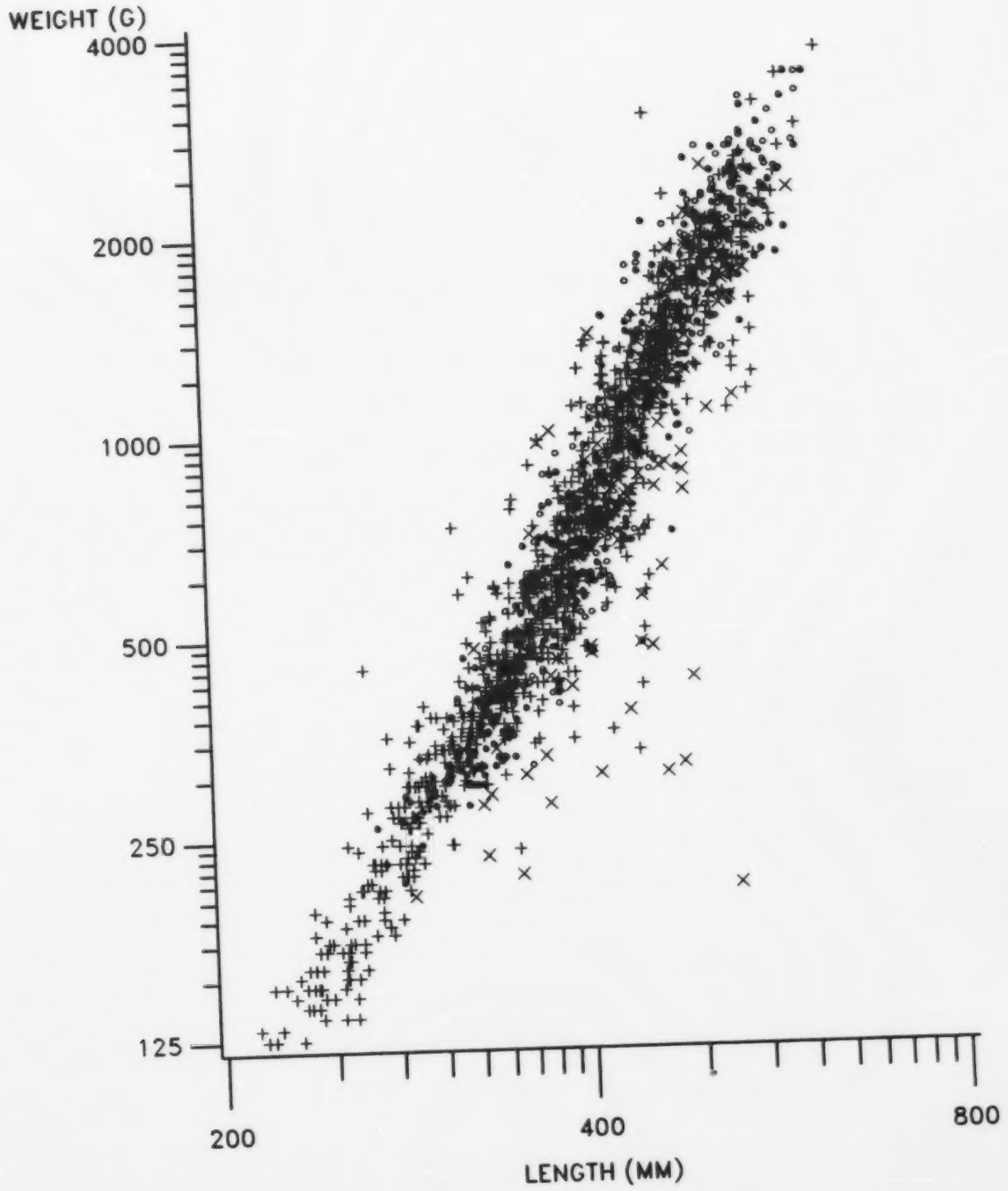

Fig. 1. Weight vs length plots of all fish > 200 mm, measured up to 5 times between July 1983 and June 1986, in 3 selection categories or as mortalities in any category. Solid dots (•) identify fish in selected families; open dots (∘), mass selected fish; pluses (+)'s, random selected fish; and x's (×), mortalities. All fish < 200 mm were in the random selected group.